An Assessment of Radiation at the TOA and Surface as Derived from Satellite and Ground-Based Measurements

Under the Auspices of the GEWEX Radiation Panel

October 20, 2004

1.0 Executive Summary

2.0 Introduction

2.1 Assessment Objectives

2.1.1 Decadal variability
2.1.2 Defining accuracy of TOA and Surface data
2.1.3 Long term goal is merged TOA, Atmosphere, Sfc Data
Responsible: Rossow with Wielicki, Stackhouse, Raschke, Ohmura

2.2 Observation System Requirements

2.2.1 Climate model natural variability: defining the limits of observing system accuracy.
2.2.2 Observing requirements driven by climate radiative forcing, cloud feedback, aerosol indirect effect issues.
2.2.3 Long term goal is climate prediction uncertainty driven requirements (climate prediction.net example)
Responsible: Rossow with Slingo/Wielicki/Stackhouse

3.0 Long-Term TOA Flux Data Product Comparisons

3.1 Brief Summary of Available Long-Term TOA products

(LW, SW, Net, All-Sky, Clear-sky)

3.1.1. ERBE Non Scanner
3.1.1.1 Description
3.1.1.2 Calibration
3.1.1.3 Conversion to fluxes and time integration
3.1.1.4 Need to complete nonscanner data: 1999-2004
Responsible: Wielicki, Wong

3.1.2 ERBE Scanner
3.1.2.1 Description
3.1.2.2 Calibration
3.1.2.3 Conversion to fluxes and time integration
3.1.2.4 Need to reprocess ERBE scanner with CERES ADMs
Responsible: Wielicki, Wong, Young

3.1.3 CERES Scanner
3.1.3.1 Description
3.1.3.2 Calibration
3.1.3.3 Conversion to fluxes and time integration
Responsible: Wielicki, Priestley, Loeb, Young

3.1.4 GEWEX SRB
3.1.4.1 Description

3.1.4.2 Calibration
3.1.4.3 Conversion to fluxes and time integration
Responsible: Stackhouse

3.1.5 ISCCP FD
3.1.5.1 Description
3.1.5.2 Calibration
3.1.5.3 Conversion to fluxes and time integration
Responsible: Rossow, Zhang

3.1.6 ScaRaB
3.1.6.1 Description
3.1.6.2 Calibration
3.1.6.3 Conversion to fluxes and time integration
Responsible: Vollier, Duvel

3.1.7 NOAA Pathfinder: HIRS
3.1.7.1 Description
3.1.7.2 Calibration
3.1.7.3 Conversion to fluxes and time integration
Responsible: Ellingson

3.1.8 NOAA Pathfinder: AVHRR
3.1.8.1 Description
3.1.8.2 Calibration
3.1.8.3 Conversion to fluxes and time integration
Responsible: Heidinger, Lazlo

3.1.9 Model Re-Analyses
3.1.9.1 NCEP R2 *Yang?*
3.1.9.2 ERA-40 *Morcrette*
3.1.9.3 GEOS-4 *Wu*

3.2 TOA Flux Comparison Studies

3.2.1 Monthly Gridded Maps
Parameters: for All-sky and Clear-sky (Type 1&2)
- SW up, LW up, SW down
- for entire record length
- in native grid
- if diurnal cycle include 3-hourly monthly
Responsible: (Rossow, Wielicki, Stackhouse, Harries, Hollmann)

3.2.2 Monthly Time Series: Global Land/Ocean, Zonal Land/Ocean

- parameters same as in item 3.2.1
- Hoffmeiller Latitude/Time: monthly by native grid latitude steps
- viewable picture plus downloadable ascii files

Responsible: (Rossow, Wielicki, Stackhouse, Harries, Hollmann)

3.2.3 Seasonal Gridded Map of Diurnal Cycle

- provide Time of Max, Time of Min, Max-Min Amplitude
- every season in data set.
- DJF, MAM, JJA, SON
- diurnal cycles constructed by averaging at each local time of day then over month/season

Responsible: (Rossow, Wielicki, Stackhouse, Harries, Hollmann)

3.2.4 Characterize Variability of Global, Zonal, Regional

3.2.4.1 Observation Variability

- provide Tables of variability
- land and ocean separated
- standard deviation for the same TOA flux parameters as in 3.2.1 and same surface flux parameters used in 3.3 comparisons
- instantaneous, daily, monthly, seasonal, annual, decadal time scales
- grid scale for all time scales
- zonal, global for monthly to decadal time scales
- provide for all observation data set (e.g. ERBE, CERES, SRB, FD, GERB)

Responsible: Rossow, Wielicki, Stackhouse, Harries, Hollman

3.2.4.2 Model Variability

- same variables and space/time scales as observations in 3.2.4.1
- provide for Climate Models in coupled ocean/atmoshere runs with fixed boundary conditions (long-term equilibrium control runs) (e.g. UKMO, NCAR, CCSR, GFDL, MPI, LMD)
- provide for Climate Models in coupled ocean/atmosphere 20th century forcing runs. same models as fixed boundary conditions
- provide for Reanalysis Models (e.g. ERA-40, GEOS-4, NCEP/NCAR)
- used for setting observation requirements and for evaluation of model variability.

Responsible: Slingo contact modeling centers)

3.2.5 Meteorological Regimes and Cloud Systems

3.2.5.1 Meteorological Regime Classification

- Use ISCCP cloud data to classify regimes by cloud pressure/tau frequency distributions. One type for each 250km grid box and each day. Two latitude bands15S to 15N, and 30-65N and 30-65S.
- Have surface sites classify regime using these daily grid box classifications
- Provide co-locator tool to provide classification for any specified lat/lon/day

Responsible: Jacob, Rossow

3.2.5.2 Cloud System Classification

- Instantaneous Cloud Systems from CERES data will be provided for 4 cloud types: trade cu, broken stratus, stratus, and deep convection
- For each cloud system provide location, size, time, cloud physical properties, TOA and Surface fluxes, and ECMWF or GEOS-4 meteorological state profiles (T,q,wind) and advective tendencies.
- Initially Jan-Aug 1998, Mar 2000 TRMM data later additional CERES months.
- provide co-locator tool for finding cloud systems given lat/lon/time.

Responsible: Xu.

3.2.6 Time Series at Selected Surface Sites

3.2.6.1 Surface flux working group identifies list of surface sites for long time series comparisons to satellite data. Includes BSRN, ARM, CMDL,SEAFLUX (ships and buoys), Ocean Reference Buoys (Weller)

3.2.6.2 Clarify impact of 3-hourly average flux (FD, CERES), versus instantaneous 3-hourly flux (SRB)

3.2.6.3 Time series plots of satellite/surface comparisons

- satellite grid box to individual surface sites
- satellite grid box to average of sites in box
- satellite pixels to surface sites

3.2.6.4 Time series done for both TOA and Surface satellite fluxes and surface site flux.

Responsible: Rossow: will subset FD over surface site, Rutan will subset CERES (CAVE), Stackhouse will subset SRB

3.2.7. High Time/Space Resolution Comparisons: June and July 2004

- global, but focus on GERB/MSG area
- focus on diurnal cycles
- TOA/SFC combined activity
- Provide full space/time resolution of all data
- Expect spring 2005 availability of CERES and GERB. ISCCP/FD/SRB by Dec 2004.
- SAFs
- CEOP sites (DAAC subset sat data?)

Responsible: (Rossow, Wielicki, Stackhouse, Harries, Hollmann), Dutton, Other surface sites, Valencia

3.2.8 Error Budget at Varying Time and Space Scales

- statistics for errors include
- mean, stddev of each data set (validating and estimating)
- mean stddev of difference of two data sets
- correlation coefficient of two data sets
- slope of regression, uncertainty of slope
- intercept, uncertainty of intercept
- number of points used in comparison
- 20-50 km: instantaneous, daily, monthly, annual, decadal. bias/sigma
- 100-250km spatial: instantaneous, daily, monthly, annual, decadal
- zonal monthly, annual, decadal
- global monthly, annual, decadal

- cloud regimes: 250km, instantaneous, daily, monthly, annual, decadal
- all-sky vs. clear-sky
- objects, instantaneous, daily, monthly, annual, decadal
-taylor diagrams and scatter plots for visualization and table of numbers

Responsible: (Rossow, Wielicki, Stackhouse, Harries, Hollmann)

3.3 Assessment Web Site Support

- Web site supported by NASA Langley DAAC or GEWEX web site
- Support for monthly data sets
- All data available and freely accessible
- Current versions of assessment documents, including text drafts
- Current versions of contributed analyses and results
- Pointers to all full resolution data sets
- Full resolution data for June and July 2004.

Responsible: Wielicki and Rossow

4.0 Long-Term Surface Flux Data Product Comparisons

4.1 Surface Networks and Measurements

4.1.1 Poll of existing measurement networks (i.e., GEBA, BSRN, etc.) for information related to:

- temporal and spatial extent of networks
- calibration procedures and estimates of operational uncertainty

Responsible: Dutton, Ohmura, Philipona

4.1.2 Develop surface measurement database for validation

4.1.2.1 Select sets of network site measurements for Long-term validation

- produce monthly/daily averaged datasets and put at web site
- parameters: broadband radiometric fluxes SW total (from global and direct+diffuse methods), direct and diffuse and LW

Responsible: Zhang, Stackhouse, Dutton, Ohmura

4.1.2.2 Select sets of network site measurements based upon dataset provider spatial regions (i.e., GEWEX CSE regions, experiments, ship measurements)

- data providers submit minute data (or highest available temporal resolution available) for designated periods (i.e., GERB period and another period TBD)
- parameters: broadband radiometric fluxes SW total (from global and direct+diffuse methods), direct and diffuse and LW

Responsible: Zhang, Stackhouse, Dutton

4.1.3 Surface measurement needs and issues

4.1.1.1 Spatial representativeness of sites - use satellite-data to estimate??
4.1.2.2 Unsampled climate types and regions (oceans??)
4.1.2.3 Operational uncertainties due to precipitation and other meteorological
4.1.2.4 Biases of older pyranometer measurements due to thermal offset problems
4.1.2.5 Relative importance of absolute accuracy vs. long-term stability
4.1.2.6 Summary of issues related to ocean buoy measurements
Responsible: Dutton, Ohmura, Philipona

4.2 Summary of Long-Term Satellite Surface Flux Data Products

Poll each dataset for description (i.e., parameters, space and time scales, availability, etc.), method (general description of input parameters and algorithms including assumptions made), and temporal and spatial averaging algorithms.

4.2.1 Global Data sets:

4.2.1.1 GEWEX SRB *(Stackhouse)*
4.2.1.2 ISCCP FD *(Zhang and Rossow)*
4.2.1.3 ESRB (from ISCCP C2; *Vardavas*)
4.2.1.4 CERES SARB and SOFA (*Rutan and Charlock*)
4.2.1.5 UMD Pathfinder (SW, *Pinker*)
4.2.1.6 SWnet (from ERBE, *Li and Leighton*)
4.2.1.7 MODIS based products – SW (*Pinker*)
4.2.1.8 Re-Analysis models:

- ERA 40 (*Morcrete*)
- NCEP R2 (*Yang??*)
- GEOS-4 (*Man-Li Wu?*)

4.2.1.9 GCM's from AMIP II (*Wild and Freidenreich*)

4.2.2. Regional Data Sets

4.2.2.1 GEWEX Continental Scale Experiments (*GCIP/GAPP, LBA, BALTEX, GAME*)

4.2.2.2 Brazilian products

- INPE (*Pereira-solar energy applications, Brazil only*)
- INPE/CPTEC (*operational product, all of S. America*)

4.2.2.3 Tropical Surface fluxes (SeaWifs, *Chou*)

4.2.2.4 ISCCP DX (GOES/METEOSAT) (*Pinker*)

4.2.2.5 SUNY-Albany (*Perez et al.*)

4.2.2.6 Polar Fluxes (*Key*)

4.2.2.7 MSG

a. MSG SEVIRI/GERB and NOAA (DWD-SW and LW-*Hollmann and Gratzki*)

b. MSG SEVFIRI only (DLR-SW only-*Meyer/Hollmann*)

c. MSG SEVIRI, GOES and NOAA (CMS-SW and LW *Marsouin*)

4.3 Satellite Estimate-Surface Measurement Comparisons

4.3.1 Statistical Comparisons (Bias, RMS, correlation) based on time-space scales (polar, mid-latitudes, tropics, surface climate types; use long and limited-term surface measurements)

- Parameters for comparison: All-sky and Clear-sky; SW dn, SW dir dn, SW dif dn, LW dn
- Temporal Averages: Monthly, daily averaged, monthly averaged diurnal cycles,1-3 hour average, Instantaneous

Responsible: Stackhouse, Zhang, Pinker, TBD data producers.

4.3.2 Time Series Analysis (use long-term sites only)

- Long-term mean and variability characteristics of same parameters.
- Long-term intercomparison of correlations; issues (satellite and surface measurement stabilities).

Responsible: Stackhouse, Zhang, TBD data producers.

4.3.3 Issues satellite-surface validation

- cloud and aerosol property and inhomogeneity (function of cloud type?)
- space time sampling and mismatching

Responsible: Stackhouse, Zhang, Li(?), Pinker, Rutan

4.4 Long-term Satellite-based SRB Data Product Comparisons

4.4.1 Monthly Gridded Maps: submitted by data producers

Parameters: All-sky and Clear-sky; SW dn, SW dir dn, SW dif dn, LW dn

- for entire record length
- in native grid

- if diurnal cycle include 3-hourly monthly
Responsible: (Rossow/Zhang, Stackhouse, Pinker, others?)

4.4.2 Monthly Time Series: Global Land/Ocean, Zonal Land/Ocean
- parameters same as in item 4.4.1
- Hovmeuller Latitude/Time: monthly by native grid latitude steps
- viewable picture plus downloadable ascii files
Responsible: (Rossow/Zhang, Stackhouse, Pinker, others?)

4.4.3 Seasonal Gridded Map of Diurnal Cycle
- provide Time of Max, Time of Min, Max-Min Amplitude
- every season in data set.
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- instantaneous, daily, monthly, seasonal, annual, decadal time scales
- grid scale for all time scales
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- provide for all data sets

Responsible: Rossow, Stackhouse, Pinker, Rutan

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Responsible: Wild, Freidenreich, Morcrette

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4.4.7 Summary Uncertainty Budget at Varying Time and Space Scales

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  - correlation coefficient between data sets
  - slope of regression, uncertainty of slope
  - intercept, uncertainty of intercept
  - number of points used in comparison
- Space Scales:
  - 20-50 km: instantaneous, daily, monthly, annual, decadal. bias/sigma
  - 100-250km spatial: instantaneous, daily, monthly, annual, decadal
  - zonal monthly, annual, decadal
  - global monthly, annual, decadal
- Cloud regimes: 250km, instantaneous, daily, monthly, annual, decadal
- Parameters: all-sky vs clear-sky

- Time Scales: objects, instantaneous, daily, monthly, annual, decadal
- Analysis: taylor diagrams and scatter plots for visualization and table of numbers
Responsible: (Rossow, Wielicki, Stackhouse)

4.5 Assessment Web Site Support (see 3.3)

5.0 Contributed Chapters

6.0 Lessons Learned

6.1 Data Management
- 6.1.1 Data Access and Delivery (GEBA example)
- 6.1.2 Data Analysis Tools
- 6.1.3 Data Archive: long-term archive issues

6.2 Data gap issues
- 6.2.1 Satellite
- 6.2.2 Surface

6.3 Observation vs. Climate Model Incomparisons in nonparallel world
- 6.3.1 Twilight issues
- 6.3.2 Reference altitude

7.0 Final Assessments and Recommendations

7.1 Assessment of TOA fluxes

7.2 Assessment of Surface fluxes

7.3 Assessement of Atmospheric Divergence

7.4 Identification of Key issues

Appendix: Supporting Detail for Data Error Sources and Estimates

Appendix A Satellite TOA Flux Data Product Error Analysis

A.1 ERBE Broadband Nonscanner
- A.1.1 Calibration
- A.1.2 Spectral Sampling
- A.1.3 Spatial Sampling
- A.1.4 Viewing Angle Sampling
- A.1.5 Time Sampling (includes Solar Zenith effects)

A.1.6 Gap Filling Methods (missing time/space data)
A.1.7 Error Table Summary
- by time scale: instantanous, daily, monthly, annual, decadal
- by spatial scale: pixel, grid, zonal, global
- by cloud type or meteorological regime

A.2 ERBE Broadband Scanner
Same sections as A.1

A.3 ScaRaB Broadband Scanner
Same sections as A.1

A.4 CERES Broadband Scanner
Same sections as A.1

A.5 GEWEX SRB
Same sections as A.1

A.6 ISCCP FD
Same sections as A.1

A.7 NOAA Pathfinder HIRS OLR
Same sections as A.1

A.8 NOAA Pathfinder AVHRR OLR, OSR
Same sections as A.1

A.9 AIRS OLR??
Same sections as A.1

Appendix B. Satellite Surface Flux Data Product Error Analysis

B.1 GEWEX SRB
A.1.1 Calibration
A.1.2 Spectral Sampling
A.1.3 Spatial Sampling
A.1.4 Viewing Angle Sampling
A.1.5 Time Sampling (includes Solar Zenith effects)
A.1.6 Gap Filling Methods (missing time/space data)

A.1.7 Radiative Model Description and Errors (If applicable)
A.1.7 Error Table Summary
- by time scale: instantanous, daily, monthly, annual, decadal
- by spatial scale: pixel, grid, zonal, global
- by cloud type or meteorological regime

B.2 ISCCP FD
Same sections as in B.1

B.3 CERES
Same sections as in B.1

B.4 ESRB
Same sections as in B.1

B.5 U.Md.
Same sections as in B.1

Appendix C. Surface Site Radiative Flux Data Products Error Analysis

C.1 BSRN
C.1.1 Calibration (Direct, Diffuse)
- Absolute, Stability, Precision, Drift between calibrations
C.1.2 Effects of icing, precipitation, condensation
C.1.3 Pointing (shading, direct beam)
C.1.4. Site Specific Corrections (e.g. obstructions)
C.1.5 Gap Filling
C.1.6 Site surface homogeneity, horizontal representativeness

C.2 CMDL
same as C.1

C.3 SURFMAP
same as C.1

C.4 GEBA
same as C.1

C.5 WRDC
same as C.1

C.6 IMET/Ocean Buoys
same as C.1

C.7 Ocean Ships

same as C.1

Appendix D. Radiative Model Comparisons

D.1 Model Descriptions

D.2 Model Results in ICCRCM

D.3 Sensitivity to Input Parameters (table example from Rossow)

D.4 Comparisons using Data Products

D.5 Input Data Sources

D.5.1 Surface Albedo Maps
D.5.2 Surface Emissivity
D.5.3 Aerosol
D.5.4 Solar Spectrum and Solar Constant
D.5.6 Cloud Particle Optics